# CONSTRAINTS TO USING FIRE AFTER HURRICANE HUGO TO RESTORE FIRE-ADAPTED ECOSYSTEMS IN SOUTH CAROLINA

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## ABSTRACT

The role of disturbance in maintaining diversity at landscape scales is now widely recognized. Catastrophic events, such as severe hurricanes, are part of the natural disturbance regime in eastern U.S. forests, perhaps playing a key role in the long-term functioning of many ecosystems. In the South, the combination of hurricanes and fire is an important interactive disturbance, although little is known about their ecological consequences. An opportunity to mimic this natural process, in order to favor development of fire-adapted plant communities, presents itself after severe hurricanes in present-day coastal plain forests. A series of planned fires following a stand-replacement hurricane event, over time, might result in transition to prairie, pine savanna, or open flatwoods community structure and composition.

On the Francis Marion National Forest in South Carolina, the use of prescribed fire is a critical component of ecosystem management. However, obstacles exist to using prescribed fire after Hurricane Hugo. Post-hurricane fuel loading, particularly the great quantities of large woody debris, has created a difficult situation for land managers when they attempt to use prescribed fire. The combination of strict emissions guidelines, difficulty in extinguishing smoldering large fuels, high potential for atmospheric inversions, and expanding wildland-urban interfaces has created a nearly untenable situation where liability issues often take precedence. Currently, fire use is confined to lower-risk areas. The future of ecosystem management using prescribed fire is uncertain, and opportunities to restore and manage longleaf pine (*Pinus palustris*) ecosystems on a large scale are in jeopardy.

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## INTRODUCTION

Catastrophic events, such as severe hurricanes, have become recognized as part of the natural disturbance regime in forests (Weaver 1989), and are now thought to play important roles in the long-term functioning of ecosystems (Lugo et al. 1983, Boucher 1990). In southern U.S. coastal plain forests, from Texas to Virginia, the combination of hurricanes and fire was an important disturbance, although little is known about the ecological consequences of these disturbances (Myers and Van Lear 1998). The climate and ocean proximity that support the arrival of hurricanes to the Atlantic and Gulf coastlines have likewise invited a burgeoning human population. While natural disturbance regimes of hurricanes and fire suggest great promise for the use of prescribed fire in restoration of fire-dependent natural communities, the concerns of an ever-expanding coastal population will ultimately dictate if and how fire can be used in post-hurricane recovery and management efforts.

After Hurricane Hugo, a unique opportunity existed, and continues to exist to some degree, to begin restoring and managing fire-adapted communities in coastal plain forests in South Carolina. We hypothesized that a series of planned fires following a severe hurricane, perhaps coupled with reintroductions of key plant species, may, over time, result in restoration of pine savanna or prairie structure and composition. Following Hurricane Hugo, fire prescription treatments were initiated on the Francis Marion National Forest (FMNF) by both forest managers and researchers.

It soon became apparent that there were obstacles to this approach. Burning in heavy post-hurricane fuels magnified smoke management and urban interface issues far beyond previous local experience. This, plus other changes on the FMNF, a forest increasingly interlaced with roads and residents, created a nearly untenable situation for post-hurricane forest recovery via prescribed fire. Before fire can be extensively used after hurricanes in the South, a number of practical issues need to be addressed, including: (1) fuel consumption and quantities of emissions produced; (2) fire behavior and containment in post-hurricane fuels; (3) smoke management under conditions of prolonged

smoke production from large smoldering fuels, especially when temperature inversions are likely; (4) effects of burning on human health and safety, especially near urban interfaces; (5) public education as to the trade-offs between prescribed fire and wildfire; and, (6) expanded public participation and broader-based support for prescribed fire on public lands.

Our objectives in this paper are to explore opportunities to restore longleaf pine ecosystems using prescribed fire after hurricanes occur, and to address the managerial and social limitations involved in such an approach.

## OPPORTUNITY TO RESTORE LONGLEAF PINE ECOSYSTEMS

On 21 September 1989, residents of the Southeast were reminded of the power of hurricanes as Hugo approached the coast of South Carolina. After midnight, Hugo came ashore north of Charleston as a Category 4 storm. Weakening only slightly, the storm sustained winds of 121 miles per hour (195 kilometers per hour) as it moved inland over the FMNF. Estimated maximum gusts were as high as 147 miles per hour (235 kilometers per hour), with the eyewall of hurricane-force winds affecting an area at least 62 miles (100 kilometers) wide (Hook et al. 1991). Despite the extensive loss of forest resources, forest managers and scientists soon recognized that the storm-damaged forest provided a unique management and research opportunity. Plans were developed to use prescribed fire in this setting to restore and study diverse, fire-maintained coastal plain ecosystems.

Hurricanes are not infrequent disturbances. It has been suggested that at many locations in the coastal South, a Hugo-strength storm (sustained winds of 131 to 155 miles per hour; 210 to 248 kilometers per hour) has a 60% chance of occurring every 100 years and a near 100% chance of occurring every 400 years (Hooper and McAdie 1995). Stand-replacement disturbances of this frequency have important ramifications for community development and succession in areas where tropical cyclone regimes are severe (Lugo et al. 1983). Disturbances in this region are not limited to those of natural occurrence. Three centuries of European settlement in the southern U.S. have created drastic landscape changes, including the widespread reduction of longleaf pine ecosystems (Frost 1993, Landers et al. 1995). Very little of the remaining forest retains structure and composition of the original, fire-maintained longleaf forests and savannas (Frost et al. 1986, Platt and Rathbun 1993). As a result, regional biodiversity has declined and many characteristic plants and animals have become scarce (Roberts and Oosting 1958, Hardin and White 1989, Guyer and Bailey 1993, Peet and Allard 1993, Walker 1993).

Catastrophic windstorms create an opportunity for resource managers to modify the composition and structure of vegetation on a large scale. The increased use of prescribed fire after severe hurricanes may cause the return of fire-adapted species resulting in communities similar to those of the pre-Columbian period. Options for enhancing post-hurricane plant communities are numerous on lands with remnants of previous fire-adapted communities. On lands that had been managed for timber with fire as an element of management, that opportunity may be present. Restoration of diverse and esthetically appealing ecosystems that were once a major part of the southern landscape would constitute wise stewardship.

## HURRICANES AND FIRE

Hurricanes predispose forests to fire (Webb 1958, Gill et al. 1990, Loope et al. 1994). Large quantities of woody fuels are created, especially during severe storms. Overstory removal creates open conditions favoring increased production of fine live fuels and rapid fuel drying. In the absence of fire, woody vegetation can dominate in as little as 2 years after a hurricane (Myers 1996). Aggressive regrowth of trees and shrubs, plus litter accumulation, suppresses growth of fire-adapted ground cover plants, reducing species richness.

Frequent, on-going fire after hurricanes would favor a diverse array of herbaceous plants and fire-adapted shrubs, plus longleaf pine. On the FMNF in South Carolina, various characteristic savanna forbs (*Erigeron vernus, Polygala lutea, Rhexia mariana, Viola primulifolia,* and *Solidago* spp.), plus grasses (*Andropogon* spp., *Panicum* spp.) and shrubs (*Ilex glabra, Myrica cerifera, Gaylussacia frondosa, Rhus copallina*) colonized sites in the two growing seasons following post-hurricane experimental prescribed fires. These burns killed dense natural regeneration of 2-year-old loblolly pine (*P. taeda*) and hardwoods that proliferated after Hurricane Hugo (Myers 1996).

Limited technical information is available about fire behavior in the extremely heavy fuels that can accumulate after severe hurricanes in the South (Wade et al. 1993). It is clear, however, that under these conditions fire hazard is great and wildfires could burn with high intensity until the heavy fuel loads have been reduced by decay. Although few examples of this scenario exist, it suggests that fires of high intensity historically followed severe hurricanes in forests of the southern U.S.

Immediately following Hurricane Hugo, aggressive fire prevention was the primary fire management strategy used in South Carolina (Miranda 1996). Although totally excluding fire from areas with heavy fuel concentrations may seem reasonable, there has been considerable debate over the efficacy of that strategy (Saveland and Wade 1991). The fine fuels crucial to fire behavior accumulated rapidly in the absence of an overstory, while the larger fuels continued to dry. Each year of live fuel growth added to the problem of heavy dead fuel accumulation.

Prescribed burning to reduce fuel and manage vegetation has been reestablished on the FMNF, requiring increased staffing, planning, time, and equipment. However, increased costs of burning have prevented some sites on FMNF that could be managed for long-

leaf pine and associated fire-adapted plants from being worked into the burning rotation. Because of high fuel loading, heavy traffic on local roads, and continued urban expansion, forest managers have found themselves having to reevaluate prescriptions for fire in these urban interface areas. Where burning has been reintroduced, the size of burn units has decreased because of air quality constraints, especially on particulate production. Despite the hazard created by hurricane debris, prescribed fire escapes have not been a problem. The real challenge to using prescribed burns in hurricane debris after Hugo has not been fire control. It has been smoke management!

## SMOKE MANAGEMENT AND POST-HURRICANE FIRES

Perhaps the largest problem with the use of prescribed fire after hurricanes is residual or latent smoke. Once ignited, large-diameter, resinous fuels in the form of down and standing coarse woody debris, as well as stumps and root systems of windthrown trees, continue to produce smoke for days. Smoldering combustion continues long after the passage of the fire. Costs for mopping-up fires after hurricanes are high because of the vast amount of large, down and standing fuels. Liability issues, particularly those associated with vehicle accidents, are present even with a heavy investment in smoke mitigation.

Fuel consumption rates and smoke production during post-hurricane fires, under the range of within-prescription fuel moisture conditions, are poorly understood. Within the FMNF prescription window, large fuels, whether wet or dry, can smolder for days. Even with outer layers dry, these fuels usually exhibit a steep moisture content gradient. Most fuels are resinous pines. These conditions result in prolonged smoke production. Burning under very dry fuel conditions might shorten smoke production periods, but would result in unacceptable fireline intensities and the associated higher risk of escapes. Burning on pre-frontal winds could be part of the answer, as rainfall associated with the frontal passage would assist in extinguishing large fuels. FMNF fire managers have found that their best tool for smoke mitigation is aerial ignition. This rapid firing method creates stronger convection, getting smoke up and away from sensitive areas. Aerial ignition also allows more acres to be burned on those days when conditions are suitable for minimal smoke production and/or impacts.

Managing heavy loads of post-hurricane fuels is made more difficult because each year the extent of decay increases, causing fuels to settle. Over time, arrangement and fuel bed porosity change drastically, altering ignition and consumption behavior. These dynamics alter smoke generation and duration in ways that, while generally understood, cannot be accurately predicted given the current state of knowledge and available models.

This problem is especially serious in coastal plain areas such as the FMNF, where nightly atmospheric inversions are the norm, and drifting smoke is trapped close to the ground. Winds are typically light and erratic. Smoke may travel with light winds or may move down-slope, even in areas with slight elevation change. While weather forecasts and local experience assist in predicting smoke movement, neither can determine exact smoke locations at any one point in time. Continuous monitoring of nighttime road conditions is conducted to protect motorists. Patrols constantly track the smoke, moving blinking hazard signs and notifying local law enforcement agencies if visibility dictates a road closure.

The expanded wildland-urban interface dramatically reduces the ability of fire managers to mitigate smoke management concerns such as risk of liability and smoke intrusions. Increasing air quality restrictions further complicate the situation. Good smoke management can lessen, but not eliminate, the visibility problem for highways and airports, and air quality concerns in nearby cities and towns. An increasingly health-conscious (and litigious) public, and the officials representing the public interest, are not usually receptive to compromising air quality in the name of forest health. Conversely, the increased possibility that damaging wildfires will occur in the absence of prescribed burning, with destruction of property, increased potential for loss of human life, and greater particulate production, is seldom recognized by the general public. Clearly, the public must be informed about the trade-offs between burning and not burning in the context of ecosystem management.

## PUBLIC HEALTH AND WELFARE

The adverse effects of particulates and other components of smoke to human health have been reported (USDA Forest Service 1995a), and continue to generate considerable public concern. Prodded by organizations promoting air quality, regulators are implementing increasingly stringent limits on particulate production. At the same time, there is a growing appreciation that the elimination of prescribed burning in wildlands may defer particulate production until wildfires occur. "Protection" from an immediate risk that directly increases vulnerability to a multitude of deleterious long-term risks does not appear to comprehensively consider human health and welfare.

Persons living in the wildland-urban interface are profoundly affected by decisions to use or exclude prescribed fire following a hurricane. Many will directly experience both the desirable and undesirable outcomes from prescribed burning, or from wildfire. Given adequate information on the numerous risk issues involved with fire management decisions, what choices would the local public make for post-hurricane management of their neighboring wildlands? Is there sufficient flexibility in the policy-making process to allow local self-determination by the populace most impacted by such decisions?

## FIRE EXCLUSION TRADE-OFFS

People's opinions about fire in relation to human safety and health concerns may be the most important and difficult of all challenges relating to fire and ecosystem management (Wade *this volume*). The public is unlikely to support a practice that it does not understand and that causes inconvenience and potential harm. Increased efforts to identify, measure, and communicate the various effects of, and differences between, wildfire and prescribed fire are needed to help the public reach an informed decision regarding prescribed fire. What are the trade-offs made for both the human and forest communities? What is the trade-off for increased wildfire risk as a consequence of attempted fire exclusion? Increased incidence of wildfires, alteration of natural habitats (with a concurrent loss of some game species and forest products), and reduced biodiversity are all likely results of total fire suppression. These consequences are undesirable to a large segment of the concerned public and should be included in education efforts about prescribed burning in ecosystem management. Greater support of burning will likely only result from a balanced presentation of the trade-offs between wildfire and prescribed fire.

Another issue facing natural resource managers is the problem of conflicting statutes. For example, land managers failing to provide adequate levels of prescribed burning for fire-dependent endangered species may face legal consequences. While the Endangered Species Act (ESA) has not been widely interpreted in this manner, agencies that fail to adhere to their own management plans may be found liable, as with the case involving national forests in Texas (USDA Forest Service 1995b). In this precedent-setting litigation, the Forest Service's own management practices were found to constitute a "taking" of the red-cockaded woodpecker (*Picoides borealis*) in violation of the ESA, in part due to inadequate levels of hardwood midstory control that could have been accomplished with prescribed fire.

It is also conceivable that land managers may be held liable for allowing hurricane-produced fuels to cause wildfires. A catastrophic wildfire burning in hurricane-affected forestland that had not been prescribe burned may be seen by the affected public as an example of irresponsible management. Clearly, managers are in a sensitive and difficult situation that demands a thorough analysis of any burning program, and then strong organizational commitment at all levels to implement the decisions reached.

## INNOVATIVE APPROACHES

Maintaining the ability to use fire will become more difficult as forests like the FMNF become increasingly urban. Although good planning and execution of prescribed burns minimizes the threat of escapes, liability issues from smoke will likely continue as long as there are fires, whether prescribed or wild.

Methods to minimize smoke production and prevent hazardous smoke concentrations are an integral part of every fire prescription. Fire managers already tailor firing techniques and ignition patterns to site-specific fuel and weather conditions in order to manage smoke production, transport, and dispersion. As smoke and fire behavior modeling techniques improve, they will undoubtedly help minimize smoke-related human health and safety risks.


Fig. 1. Changeable message signs (CMS) are commonly in use on road construction sites to warn motorists of hazardous conditions ahead. Solar-powered CMS models are low-maintenance, reliable, proven effective, and could be used in wildland-urban interfaces to help avoid prescribed fire smoke-caused highway accidents.

Mitigating effects of smoke production should be approached in several ways. The impact of smoke to highway traffic is, to a large degree, determined by motorist response. Attempts to influence motorist attitude and behavior to smoke conditions may have merit. Programs aimed at informing and warning targeted driver groups need to be carefully designed and delivered. Additionally, a broader media message on the merits of prescribed fire, as well as the hazards, should be widely distributed, as some state forestry organizations have already done.

Many state highway departments use changeable message signs (CMS) to warn of construction dangers and to protect highway workers (Figure 1). New CMS models are solar powered, inexpensive to maintain, and are relatively simple to move. Signs have well-documented effectiveness in highway construction situations, and are readily available for lease or sale from private vendors. CMS are available with eight and nine character string capacities and could be easily programmed to display a three-part series of appropriate prescribed burn warning messages such as: "WARNING! SMOKE AHEAD," "CONTROL BURN IN PROGRESS," "SLOW TO 25 MPH." While lease rates are expensive (about $2,500 per month), the costs of using CMS should be evaluated in comparison to the potentially exorbitant alternatives of litigation and wildfires. CMS technology is one example of the type of innovative approaches that are becoming necessary to help maintain fire as a tool for ecosystem management, particularly in areas near rapidly expanding urban interfaces.

The other element to managing traffic is managing

the road. Many urban wildland areas are attempting, even with a large percentage of transient, nonlocal traffic, to manage speed limits on roads. Although this is generally implemented for protection of a particularly vulnerable wildlife species, it suggests resource managers at least consider what options they have for cooperative agreements with state road agencies, some which have a right-of-way through the forest contingent on their compliance with forest objectives. If speed restrictions and temporary road closures are needed to allow prescribed burning, such actions should be explored.

Finally, no recommendation made thus far would be as powerful as the increased development of strong partnerships between prescribed fire interests and the local communities. Bringing together a variety of people to promote understanding and education could forge a broader base of prescribed fire proponents. Involving community leaders and natural resource professionals representing a wide spectrum of views regarding fire use or exclusion will promote a shared sense of responsibility to better manage fire-adapted ecosystems.

## SUMMARY

Fire is a required element for maintaining many ecosystems, including the longleaf pine-grassland systems of the southern U.S. The use of prescribed fire after hurricanes should be recognized and embraced as a unique opportunity to help restore large land areas to diverse, stable, fire-dependent systems similar to those that once dominated this region.

On the Francis Marion National Forest in South Carolina, the use of prescribed fire is a critical element of ecosystem management. However, fuel loads produced by Hurricane Hugo, particularly the enormous quantities of large-sized fuels, have created a smoke management nightmare. The combination of strict particulate compliance guidelines, the high potential for atmospheric inversions, difficulty in extinguishing large areas of smoldering fuels, and expanding wildland-urban interfaces, has created a nearly untenable situation where liability issues take precedence over resource management objectives. Land managers are damned if they do burn, but could eventually be damned if they do not.

Currently, use of prescribed fire is confined to lower-risk areas on the FMNF. Despite strong support from local environmental conservation interests, numerous challenges remain to the continuance of a strong prescribed burning program. Innovative approaches will be required to safeguard motorists from smoke on roadways. Programs must be developed to inform the public about the simple reality that forests can either be burned under prescription, or will eventually burn, with potentially devastating results by wildfires.

The challenge for restoration of forest health in other ecosystems harbors similar issues. As resource managers, we need to take the lead to dispel the common misconception that merely setting aside a forest or grassland protects it. We need to improve our efforts to communicate that forest protection, for many systems, requires active management plus public tolerance for temporary impairments to the human environment. Without a broader base of public understanding and support, we will miss opportunities to restore longleaf pine ecosystems and make inroads into development of new approaches to forest stewardship.

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